B. ELECTRICITY CONSUMPTION

This appendix details additional information on electricity consumption and the derivation of hourly profiles which are needed to run unit commitment and economic dispatch simulations.

Firstly, the method of normalizing electricity consumption is explained. Secondly, it is explained how this yearly (normalised) electricity consumption is translated into hourly profiles for each simulated climatic year. Finally, a focus is made on how the electrification of the industrial sector is included in the hourly profiles.

B.1. NORMALISATION OF THE ELECTRICITY CONSUMPTION

Normalisation is a way to look at electricity consumption while cancelling the effect of the temperature (which currently drives a small part of electricity consumption in Belgium). Even in Belgium, although the impact of the temperature on electricity consumption is still relatively limited, it can still result in a non-negligible correction.

Therefore, it is indeed important to use normalised consumption when, e.g.,

- comparing electricity consumption between different years on a consistent basis;
- creating hourly load profiles for different climate years.

To construct hourly load profiles for different climate years, the daily temperatures of each climate year are used as input together with the normalised hourly load profile. This enables to consider the temperature effect of each climate year.

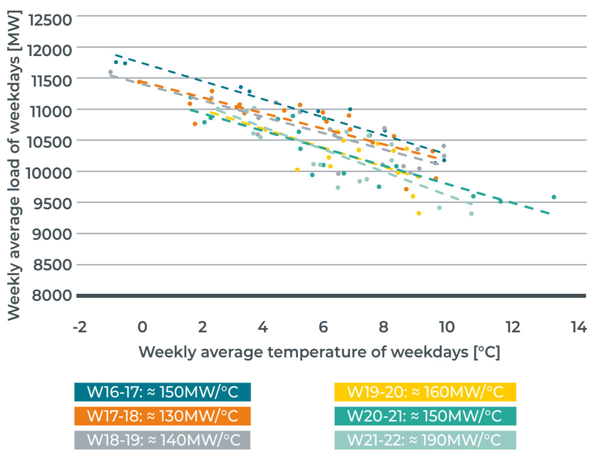
In order to normalise the electricity consumption, several parameters should be taken into account. In this study, the temperature but also the number of days per year and the number of working days are considered.

To perform a normalisation, Heating Degree Days (HDD) are used. HDD is a commonly used measure of how cold the temperature was during a given period. It is calculated as the difference between the reference temperature (or a chosen value) for a specific location and the average temperature of that location, for a 24-hour period or a several days. The higher the HDD value, the colder the temperature was over the period.

Different definitions of HDD exist depending on the reference temperature used or the period of time and associated weights defined. The calculation of HDD in this study for Belgium is based on the Synergrid methodology and data (HDD are primarily used in the gas sector to determine consumption patterns). The HDD for a specific year is used and compared to the HDD of a normal year, which is calculated as the average HDD over the last 30 years. In this case, the HDD of a normal year is 2252 [SYN-1]. Note that normalisation can happen on any reference amount of heating degree days. Hence, if it is expected that these might decrease or increase in the future, the normalised demand would decrease or increase accordingly, but the future demand based on a given temperature will stay the same.

The **first step** of the normalisation is to cancel out the **temperature effect**. To normalise electricity consumption based on HDD, the thermosensitivity of electricity consumption needs to be estimated. In order to estimate the Belgian thermosensitivity to be used in this study when scaling the historical consumption, the total load from the ENTSO-E transparency platform and the temperature measured at the Uccle weather station from 2017 to 2022 are used. The weekly average load of the weekdays in MW and the weekly average temperature of the weekdays in °C are used to assess the thermosensitivity of the load as shown in the Figure B-1. Only winter months are showed and holidays are removed. Using a linear interpolation, the relation between load and temperature is obtained, with a slope of -150 [MW/°C] on average of the historical data analysed. This indicates that the Belgian electricity load decreases by around 150 MW when the temperature increases by 1 °C. As the HDD is expressed for a period of 24 hours, the thermosensitivity of the load is around 3600 MWh per HDD.

FIGURE B-1 — ESTIMATION OF THE DEMAND THERMOSENSITIVITY IN BELGIUM



The **second step** in the normalisation process accounts for the **number of working days** (as the load is typically higher on working days than holidays) and **leap years**. To account for leap years, which have an extra day (29th of February), the average consumption for one day is simply removed. If a given year has fewer working days than a typical year, the total load is adjusted. This adjustment is made by multiplying the average load difference between a working day and a holiday (calculated over the previous years) by the difference between the number of working days in the specific year and the number of working days in a typical year.

Once the thermosensitivity and the number of working days / leap years have been defined, the historical electricity consumption of a given period can be normalised.

De-normalisation:
In order to construct hourly profiles for different climate years, the hourly temperatures of each climate year are given as input. This enables to consider the temperature effect that was isolated during the normalisation by using again the thermosensitivity. Based on the temperature of a specific climate year, a number of degree days is calculated. Finally, the consumption is then 'de-normalised' to account for the effect of the temperature of a specific climate year.

An example of normalisation and de-normalisation is given in the table below (Figure B-2).

In this study, the 200 synthetic climate years from Météo-France are used (see the dedicated Appendix J on climate years). This implies that the average yearly load for the 200 climatic years is slightly different than the yearly load normalised on 30 historical climatic years. This is explained by the fact that the HDD under the 200 climate years is lower than under the 30 historical years. Due to the thermosensitivity of electricity demand this leads to a lower annual demand. Note that the assumed thermosensitivity is also expected to evolve over time, e.g. due to the increasing contribution of electric heat pumps.

FIGURE B-2 — NORMALISATION AND DE-NORMALISATION PROCESS TAKING INTO ACCOUNT DEGREE DAYS: EXAMPLE

Normalisation process : example		
Historical consumption [TWh]	**Degree Days [°C]**	**Normalised to 2300 DD [TWh]**
80	2000	80 - (2000 - 2300)*TS
85	2500	85 - (2500 - 2300)*TS
90	3000	90 - (3000 - 2300)*TS
82	2200	82 - (2200 - 2300)*TS
84	2400	84 - (2400 - 2300)*TS

De-normalisation process : example		
Assumed future normalised consumption at 2300 DD [TWh]	**For a given Degree Days [°C]**	**Future consumption [TWh]**
85	2000	= 85 - (2000 - 2300)*TS
85	2500	= 85 - (2500 - 2300)*TS
85	3000	= 85 - (3000 - 2300)*TS
85	2200	= 85 - (2200 - 2300)*TS
85	2400	= 85 - (2400 - 2300)*TS

TS = assumed thermosensitivity in TWh/°C

B.2. GENERAL PROCESS REGARDING THE CREATION OF HOURLY PROFILES

The general process for the creation of load profiles for a specific set of assumptions, market node, and target year is schematically presented in Figure B-3. The tool used is based on the methodology and tools developed in the ENTSO-E adequacy assessments. In general, the process consists of two main steps:

As a first step, the tool maps the historical relations between climate and electrical load for each simulated market node:

- For each market node, the historical relation between climate and load time series is determined (i.e. the thermosensitivity of the load);
- These observed historical relations between climate and electrical load for each market node is then applied on a set of 200 synthetic climate years, representing potential climate of 2025, to obtain the load series forecast (see the dedicated Appendix J on climate years);
- The resulting load series include historical market characteristics in terms of the amount of electrification in industry, buildings and transport but under different potential climatic conditions. Additional corrections are made through the incorporation of special days (e.g. corrections are made for holiday periods, exceptional events, etc.) and a normalised calendar is used where the 1st of January is a Monday and consisting of 365 days;
- Note that the profiles resulting from this step depend only on the climatic inputs and the historical load and are therefore the same regardless of the assumptions on total demand and electrification.

As a second step, the evolution of electricity demand needs to be taken into account. This depends on the input assumptions related to the simulated scenario and target year.

- First, the profiles including historical thermosensitivity (obtained after step 1) are rescaled to take into account the scenario-specific assumptions which can impact the historical load such as economic growth, population growth, energy efficiency etc.;
- Additionally, new forms of electrification that are not yet existing in the historical load need to be added separately as these can have their own distinctive profiles;
- Those electrification assumptions are derived from the estimated evolutions in the market of the different factors driving electricity consumption (e.g. penetration of heat pumps, electric vehicles, additional baseload, sanitary water, air conditioning). These depend on the scenario and target year simulated which are defined within the scenario quantification process. Note that these cannot simply be added by 'rescaling' the historical load. For example: in the case of heat pumps this would lead to an underestimation of the load during winter;
- These additional electrification assumptions are translated into inputs for the creation of hourly profiles for the different electrification technologies and the different components of which some are climate-dependent and climate-independent;
- Finally, the hourly profiles for these new forms of electrification are combined with the rescaled load profiles including the historical thermosensitivity to obtain the final hourly load profiles for a given scenario and target year.

FIGURE B-3 — SCHEMATIC OVERVIEW OF THE HOURLY LOAD PROFILE CREATION PROCESS

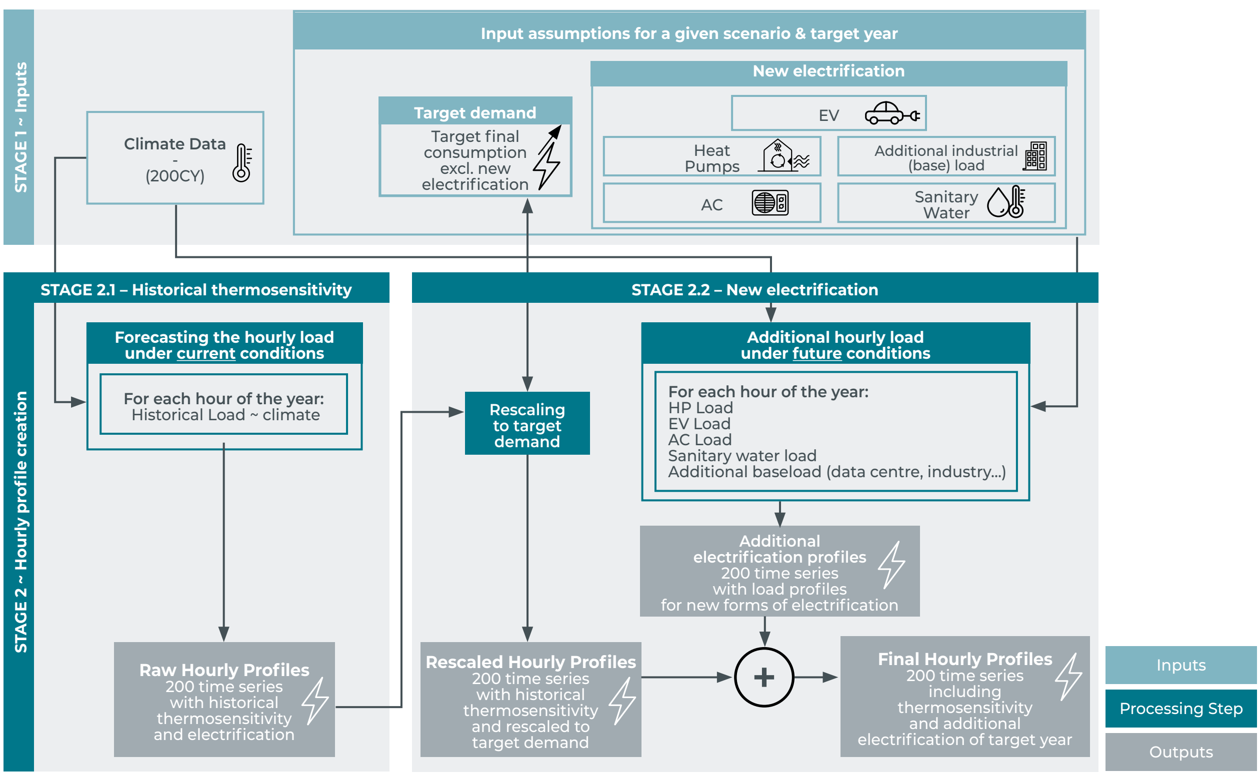


Figure B-4 shows a practical example of the different steps for the hourly load profile creation process for a given week in January. Note that this concerns a simplified example without the inclusion of air conditioning, sanitary water and new industrial loads and is not used as such within simulations. In this example EVs and HPs are added using a natural profile, clearly increasing further the peak load during evenings. This can be seen as a 'pessimistic' assumption, as the final profile for these technologies depends on their assumed flexibility (which is taken into account in the simulations) and operating mode as explained in Appendices D and E.

FIGURE B-4 — HOURLY DEMAND CONSTRUCTION – EXAMPLE WITH A WEEKLY PATTERN AND NO FLEXIBILITY

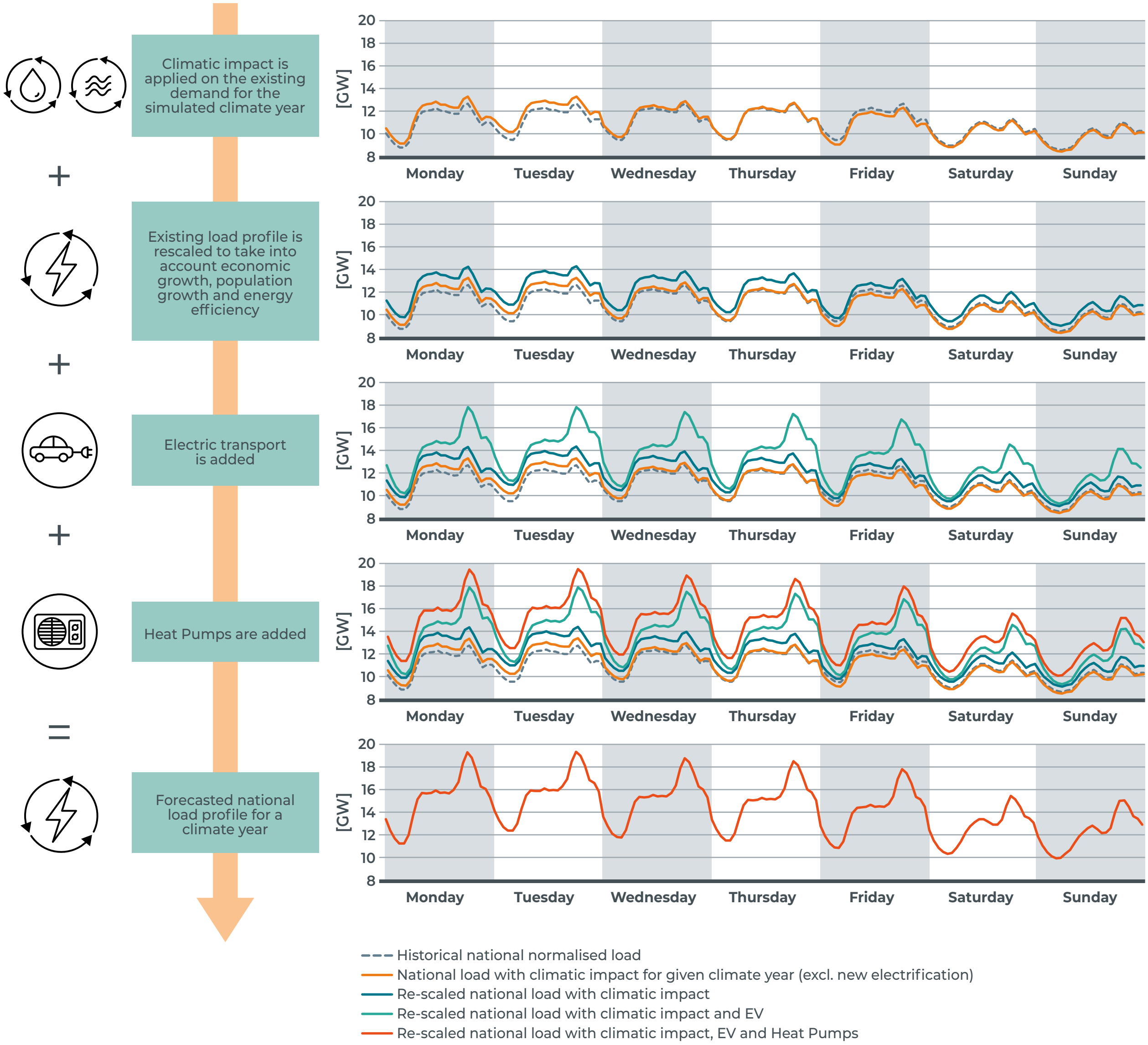
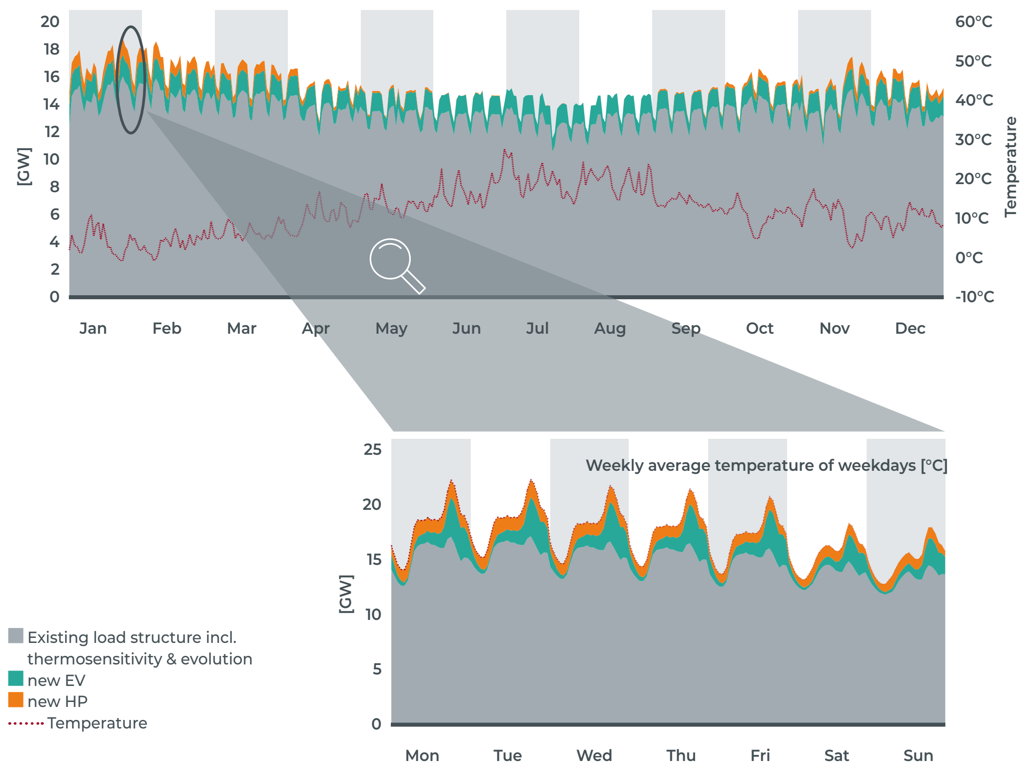


Figure B-5 presents an example of a yearly load profile resulting from the above mentioned methodology for a given scenario and target year under the historical climate year 2015. The first chart on Figure B-5 shows average daily values, the second chart of Figure B-5 zooms on the last week of January and shows the hourly load. For simplicity, new demand of industry and data centres, sanitary water heating and AC are excluded. The values are illustrative and do not necessarily correspond to real profiles used within simulations.

As explained, the grey area 'Existing load structure incl. thermosensitivity & evolution' is constructed based on the existing historical relation between climate and electricity demand. This existing demand evolves over time and is therefore rescaled to reach the target demand of those categories, subject to the assumptions taken within a given scenario. New heat pumps and electric vehicles need to be added 'on top of' these profiles as these devices do not exist in the predetermined relation between climate and electricity demand. As can be seen, lower temperatures generally increase the electricity demand. This effect becomes stronger the more heating is electrified.

In this example EVs and HPs are taken into account using a natural charging profile. As explained in the dedicated Appendices D and E, a set of different operating modes can be assumed, resulting in a different hourly profile for these categories. These yearly profiles with hourly granularity serve as an initial input into the market modelling tool (cf. Section 5), meaning that some parts of the demand which are assumed to be flexible (for example: industrial DSR, power-to-X, market-based EVs and HPs, batteries etc.) will only be 'activated' based on the market conditions in the simulations. Therefore, indicators such as the peak load are only known after performing the market simulations.

FIGURE B-5 — EXAMPLE OF A YEARLY LOAD PROFILE CONSISTING OF DIFFERENT COMPONENTS, DAILY (ABOVE) AND HOURLY (BELOW)



B.3. ELECTRIFICATION OF INDUSTRY AND DATA CENTRES

For electricity demand in industry a distinction is made between existing electricity demand and new electrification.

Existing industrial electricity demand is assumed to evolve with general macro-economic conditions, and energy efficiency. For profiling this demand is scaled with the total aggregated electricity demand (as shown in step 2 of Figure B-3 as these forms are assumed to remain structurally the same as historically.

For **new forms of industrial electrification** this load is added on top of the load profiles as those are assumed to be structurally different from the existing industrial demand. In practice, these new forms of electricity demand are assumed to power baseload industrial processes. Yet, the final related load profile depends largely on the origin of the type of demand. In general, new industrial demand can be split into 6 categories:

Power to heat – heat pumps: additional electricity demand due to fuel switching, generally from gas to electricity and for processes which require heat <200°C. Their uptake is mostly expected in the food and drink, chemical, and paper industry. These systems can be installed in combination with (existing) fossil based systems. This allows a hybrid running mode, using electricity when prices are low and vice versa. Due to their high efficiency, these units typically have a high amount of running hours. When coupled with a gas back-up, the strike price is computed as: (Heat pump eff)/(Gas boiler eff)(gas price+CO_2 price).

Power to heat – e-boilers: additional electricity demand due to fuel switching, generally from gas to electricity and for processes which require heat >200°C, typically steam. Here, uptake is especially expected in the chemical industry and for the high temperature processes in the food and drink industry. As for heat pumps, these systems can be installed in combination with (existing) fossil based systems, allowing a hybrid running mode, using electricity when prices are low and vice versa. Since the efficiency is equivalent to that of traditional gas boilers, these units will have a lower amount of running hours than industrial heat pumps, typically being activated when units with low marginal cost are setting the price. When coupled with a gas back-up, the strike price is computed as: (eletric boiler eff)/(Gas boiler eff)(gas price+CO_2 price).

Power to heat – e-ovens: additional electricity demand due to fuel switching, generally from gas to electricity and for processes which require heat >200°C. Here, uptake is especially expected in the chemical, minerals and food and drink industries. As for e-boilers, these systems can be installed in combination with (existing) fossil based systems, allowing a hybrid running mode, using electricity when prices are low and vice versa. Since the efficiency is equivalent to that of traditional gas ovens, these units will have a lower amount of running hours than industrial heat pumps, typically being activated when units with low marginal cost are setting the price. When coupled with a gas back-up, the strike price is computed as: (eletric oven eff)/(Gas boiler eff)(gas price+CO_2 price).

Direct reduction Iron – electric arc furnace (DRI-EAF): this is a technology for making primary steel by first reducing iron ore with gas (and potentially hydrogen) after which it is finally treated using EAF. Especially the electric arc furnaces require a lot of additional electricity. However, it is estimated that due to build out of excess capacity, there is a potential for load shifting within a given timeframe while still meeting production targets. In practice it is therefore assumed that (part of) this load can be shifted within a weekly timeframe, optimised based on electricity prices within that week.

Carbon capture and storage (ccs): different options exist to capture the CO_2 from industrial processes, however, all of these require additional electricity. It is expected this technology will take of in the petrochemical, cement and steel industry. Theoretically, it could be possible to deliver some flexibility, either by storing the solvent and only heat the solvent when the market prices are low and/or to make a valve where you can choose to run the waste gas through the CCS system based on market prices. However, due to the high CAPEX costs and additional complexity, the potential flexibility from these processes are estimated to be low.

Data centres: a gradual increase of data centres is expected already in the very near term. These have typically baseload electricity requirements and a very high cost in case of failure and/or black-out. Hence, even though these units have back-up generators, the value of flexibility is considered low. When flexibility is assumed it will be assumed that (part of this) load will be shed when the electricity price

Power to molecules: additional electricity demand due to the synthesis of hydrogen and e-fu- els from H2O electrolysis. It is assumed that electrolysers can provide great flexibility and optimise their running hours based on favourable market prices. This rationale is also sup- ported by the latest existing European legislation on geographical, temporal and additionally principles for the definition of renewable hydrogen [EUP-2]. In practice this means that electrolysers are assumed to never be dispatched during moments of scarcity but produce when the marginal price within the market area drops below a certain threshold.